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DESIGN & DEVELOPMENT OF CONICAL COIL EVAPORATOR TO ENHANCED THE COP

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ABSTRACT

VCRS is technology which is used daily in day to day life in domestic as well as commercial purpose. About 15 percentage of the world electricity is consumed by refrigeration system. Thus reduction of energy consumption is a major concern in vapor compression refrigeration systems. To reduce consumption of electricity of refrigeration systems, The COP should be increased. Therefore increase COP we have changed the design of evaporator coil from helical to conical design. Here we change the evaporator taper angles and torsions. However, the results show coils taper angles have the more dominant effect than the other studied parameters.

KEYWORDS: Conically Coiled Tube; COP, Vapor Compression Refrigeration System, Taper Angle, Evaporator

INTRODUCTION

There are numerous methods that were employed in the VCRS to improve its COP. They are change in design of evaporator coil, adding Nano material in system, using efficient refrigerant and LPG gas and by using hybrid VCR (HVCR). From the above noted points it is clear that there are numerous techniques that were conducted to enhance the COP of the VCRSs. However, there is still a need for the COP improvement. The geometrical parameter of the coiled tubes and the operating conditions of the VCRS affect its COP. It was demonstrated that decreasing the coil curvature increased the rate of heat transfer rate in addition to the pressure drop. Therefore, in the present study, it is aimed to investigate the effect of the geometrical parameters of coiled tubes with efficient taper angles and coil torsions on the performance attributes of the refrigeration cycle at different operating conditions.

Designing Calculation:

Design Parameter for Evaporator in tabular form

Diamentions	Conical coil Evaporator
Inner Diameter of	6 mm
Outer diamter of	8 mm
Material	copper
Thermal conducti	386 w/mk
Lengh of coil (L	508.68 cm = 16.68 = 5.08m
Outer diamter of	22.5 cm
Inner diamter of	8 cm
Number of coil	12
Height of coil	30 cm
Distance between coil	2.5 cm

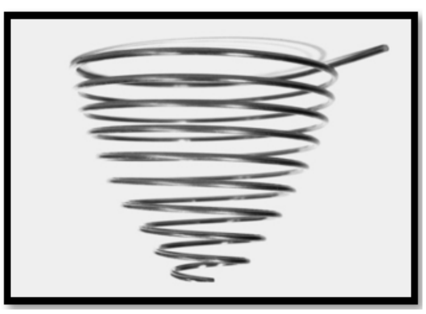


Figure: Conical coil

Analysis of The Evaporator

Thermal analysis in the heat exchangers can be done in two ways.

1. LMTD Method (Logarithmic Mean Temperature Difference)
2. NTU Method (Number of Heat transfer Units)

LMTD Method is useful when the inlet and outlet fluid temperatures of Evaporator and water are known.

NTU Method is useful when the heat exchanger is designed for the particular mass flow rate. For the given conditions LMTD Method is suitable.

1. LMTD Method:

In a heat exchanger, the temperature of the heating and cooling fluids do not in general, remain constant, but vary from point to point along the length of the heat exchanger. Since the temperature difference between the two fluids keeps changing, the rate of heat transfer also changes along the length of the heat exchanger as shown.

The rate of heat transfer can be calculated from the relation

$Q = U A \Delta T$

Since ΔT changes from point to point in a heat exchanger, we propose to use ΔTm, a suitable mean temperature difference between the two ends of a heat exchanger. The rate of heat transfer can be rewritten as

Where

ΔTm = Log Mean Temperature Difference (LMTD)

A = surface area of condenser in m2 = ΠDL

LMTD = $(\Delta T1 - \Delta T2) / \ln(\Delta T1/\Delta T2)$

$\Delta T1 = Th1 - Tc1$

$\Delta T2 = Th2 - Tc2$

$$U = \frac{1}{A_O/A_i \;\; 1/h_i + \dfrac{A_O \ln(r_o/r_i)}{2\Pi KL} + 1/h_o}$$

U = overall heat transfer coefficient in w/m2k

AO = outside tube Area in m2

Ai = inside tube Area in m2

hi = convective heat transfer coefficient of R-134(a) in w/m2k

ho = convective heat transfer coefficient of Air in w/m2k = 50 w/m2k

ro = outside radius of pipe in m

ri= inside radius of pipe in m

K = thermal conductivity of copper in w/m-k

If AO = Ai the above equation can be reduced to

$U = 1/(1/hi + 1/ho)$

Properties of R-134(a) at bulk mean temperature at various condenser speeds are taken

Bulk mean temperature of condenser can be calculated by

= (evaporator inlet temp.+ Evaporator outlet temp.)/2

In order to calculate convective heat transfer coefficient of R-134(a) the following steps are to be followed and the convection is of forced convection.

$ReD = (pvD)/\mu$

$Pr = (\mu Cp)/K$

Where

ReD = Reynolds number

p = Density of R-134(a) in kg/m3

v = velocity in m/sec = 3 to 4 m/sec

D= Diameter of the pipe in m
μ = viscosity in pa.s
Cp= specific heat in j/kgk
K= thermal conductivity in w/mk

Forced convection correlations in turbulent pipe flow are given by Dittus-Boelter
NUD = 0.023ReD *4/5 Prn
NUD = hiD/K

Where
D= Diameter of the pipe = 6x10-3m
Pr = Prandtle number
n = 0.4 for heating of the fluid and 0.3 for cooling of the fluid
The Dittus-Boelter equation is valid for 0.7< Pr <160 and ReD >10000

The Dittus-Boelter equation is good approximation where temperature differences between bulk fluid and heat transfer surface are minimal.

Nusselt number:
In heat transfer at boundary (surface) within a fluid, the ***Nusselt number is the ratio of convective to conductive heat transfer across (normal to) boundary.*** Named after Wilhelm Nusselt, it is a dimensionless number.

A Nusselt number is close to one for slug or laminar flow. It varies for turbulent flow. For forced convection,

the Nusselt number is generally a function of the Reynolds number and Prandtle number, or Nu = f (Re, Pr).

 # Heat Transfer Rate in Conical coil Evaporator
Outer diameter of Conical Coil = 22.5 cm = 225 mm
From Chart
Refrigerant entering Evaporator temperature=Tc1= 3.50 C
Refrigerant leaving Evaporator temperature =Tc2= 44 0 C
water temperature at Evaporator inlet=Th1 =50 0C
water temperature at evaporator outlet =Th2=460C
Mean temperature = (3.5+44)/2 ==24 0C
Mean temperature = 24 0C at this temperature properties are
From R-134(a) refrigerant property tables
p = 1358.8 kg/m3
D = 6 X 10-3 m
μ = 260.3 X 10-6 Pa.s
v = 529 m/s
K = 68.7 x 10-3 W/ m K
Cp= 1.132x10-3 J/kg K
Re D = (ρvD)/μ = (1358.8x 529 x 6. x 10-3) / (260.3x 10-6)= 16587812.31
Pr = (μ Cp)/K = (260.3 x10-6 x1.132x10-3)/ (68.7x10-3) = 3.56
NUD = 0.023ReD4/5 P r n = 0.023x (16587812.31)4/5 x (3.56)0.3= 20090
NUD = hi D/K
20090 = (hi 6 X 10-3)/ 68.7x10-3
hi = 230038 W/m2K
U = 1/ (1/ hi + 1/ho) = 1/(1/230038 + 1/50) = 49.98 W/m2

LMTD = (ΔT1 - ΔT2) / ln(ΔT1/ΔT2)

ΔT1 = Th1- Tc1=50-3.5=46.5
ΔT2 = Th2- Tc2=46-44=2
LMTD = 14.14

Q=Heat transfer rate through the Evaporator = U A ΔTm
A=Effective heat transfer area = 3.14 *D * L

 # Heat Transfer Rate for Helical Coil Evaporator Calculations
Sizes of tube:
Inner diameter of tube = 6 mm

For helical coil (270mm)
Outer diameter of Helical Coil = 27 cm = 270 mm
Refrigerant entering Evaporator temperature=Tc1= 280 C
Refrigerant leaving Evaporator temperature =Tc2= 33 0 C
water temperature at Evaporator inlet=Th1 =400C
water temperature at evaporator outlet =Th2=350C
Mean temperature = (28+33)/2 ==30.5 0C

Mean temperature = 30.5 0C at this temperature properties are
From R-134(a) refrigerant property tables

p = 1187.5 kg/m3
D = 6 X 10-3 m
μ = 185.8 X 10-6 Pa.s
v = 483 m/s
K = 79 x 10-3 W/ m K
Cp= 1.446x10-3 J/kg K

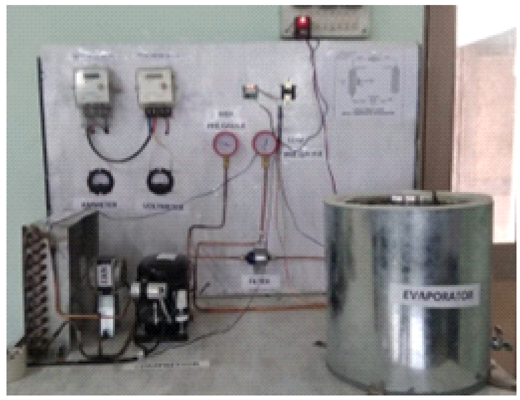
Re D = (ρvD)/μ = (1187.5x 483 x 6 x 10-3) / (185.8x 10-6) = 18521932.19
Pr = (μ Cp)/K = (185.8 x10-6 x1.446x10-3)/ (79x10-3) = 3.40

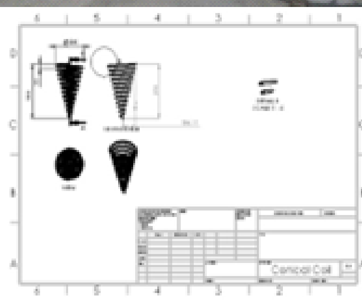
NUD = 0.023ReD4/5 P r n = 0.023x (18521932.19)4/5 x (3.40)0.3= 21643

NUD = hi D/K
21643 = (hi 6 X 10-3)/ 79x10-3
hi = 284966 W/m2K
U = 1/ (1/ hi + 1/ho) = 1/(1/284966 + 1/50) = 49.9912 W/m2
LMTD = (ΔT1 - ΔT2) / ln(ΔT1/ΔT2)

ΔT1 = Th1- Tc1=40-28=12
ΔT2 = Th2- Tc2=35-33=2
LMTD = 5.5811

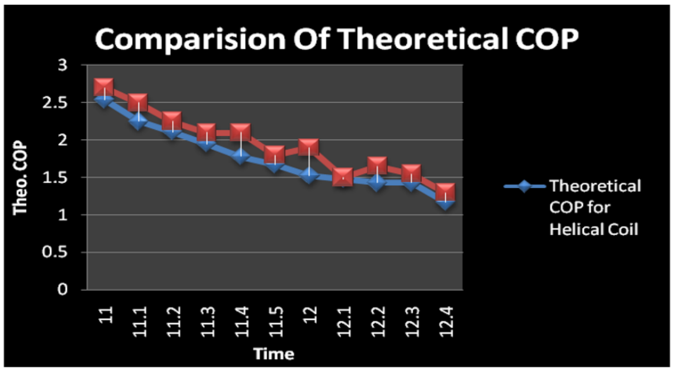
Q=Heat transfer rate through the Evaporator = U A ΔTm
A=Effective heat transfer area = 3.14 D L
Q= 49.9912xπx6x10-3x5.086x5.5811= 26.73 W

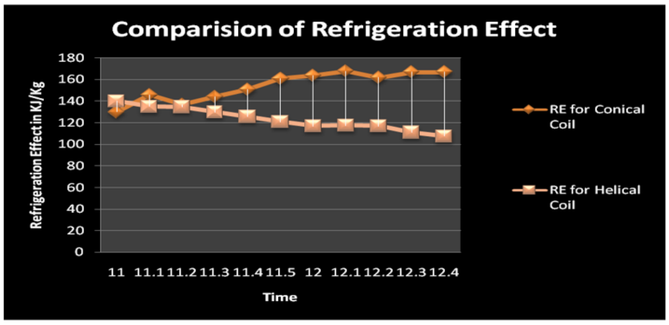




RESULTS & DISCUSSION
After performing the experiments on helically coiled design of evaporator section and conically coiled design of evaporator section. We obtained the results that COP of the conically coiled refrigeration system is greater than that of helically coiled refrigeration. It can be observed from the following table:

Readings For Conically coiled design of evaporator	
COP_{Th}	COP_{Act}
2.7	1.90
2.5	2.3
2.25	2.1
2.1	1.90
2.1	1.70
1.8	1.50
1.9	1.80
1.5	1.60
1.65	1.40
1.55	1.30
1.3	1.10
Avg=2.13	Avg=1.86





CONCLUSIONS

The major conclusions drawn based on the experimental investigations are summarized below.

The Actual and theoretical COP of the water chiller is increased by using conical coil evaporator as compared to helical coil Evaporator.

The refrigeration Effect of the water chiller is increased by using conical coil evaporator as compared to helical coil Evaporator.

The compress work for the water chiller is Decreases by using conical coil evaporator as compared to helical coil Evaporator.

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